

**KULI** software

ENERGY MANAGEMENT OPTIMIZATION

**KULI hvac**

**KULI空调模块介绍**

# What is KULI hvac? 什么是KULI空调模块?

# KULI modules 模块分布



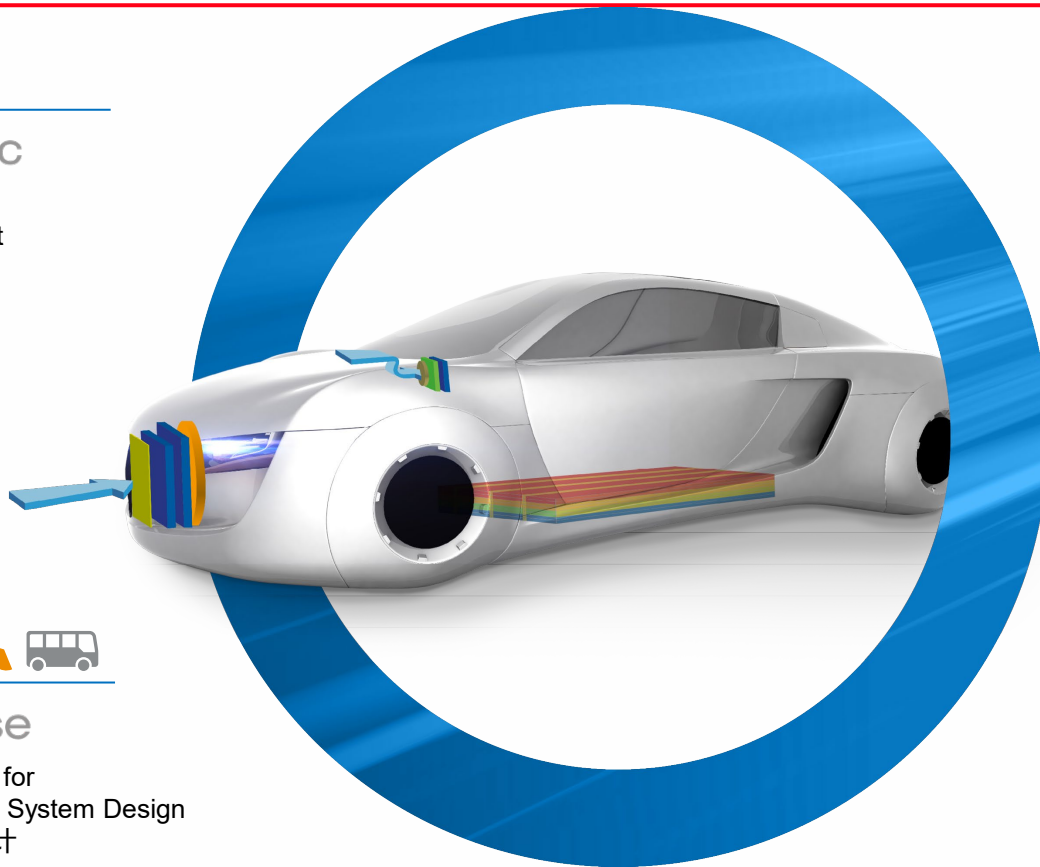
## KULI hvac

A/C and Heat Pump  
System Development  
空调及热泵系统开发



## KULI base

All your Basic Needs for  
Steady State Cooling System Design  
基础稳态冷却系统设计



## KULI drive

Drive Cycles and Engine Model  
驾驶循环及发动机模型



## KULI eco

EV Battery to Powertrain  
动力电池

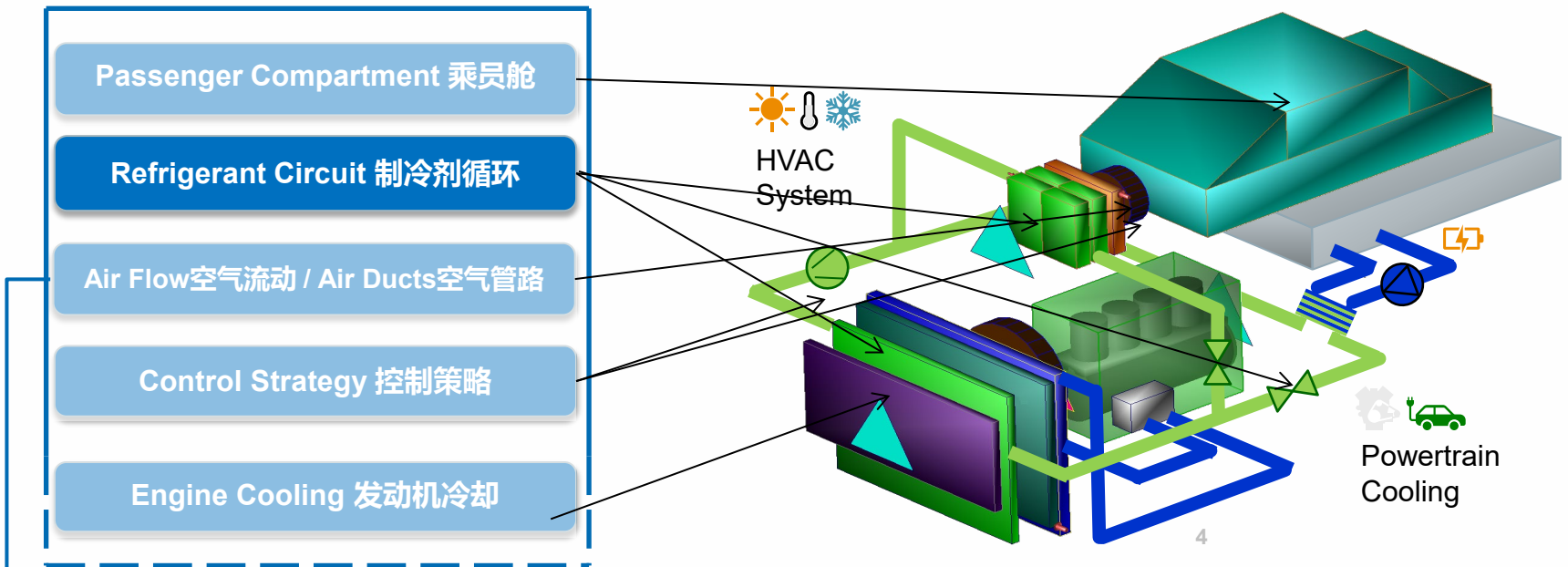


## KULI advanced

Interfaces, CFD and Optimization  
接口、CFD及优化

# HVAC System 空调系统 –

## Components and Subsystems to be considered 考虑零部件与子系统



KULI enables to speed up the product development of the HVAC system  
使用KULI加速车辆空调系统开发

# User Interface KULI 用户界面

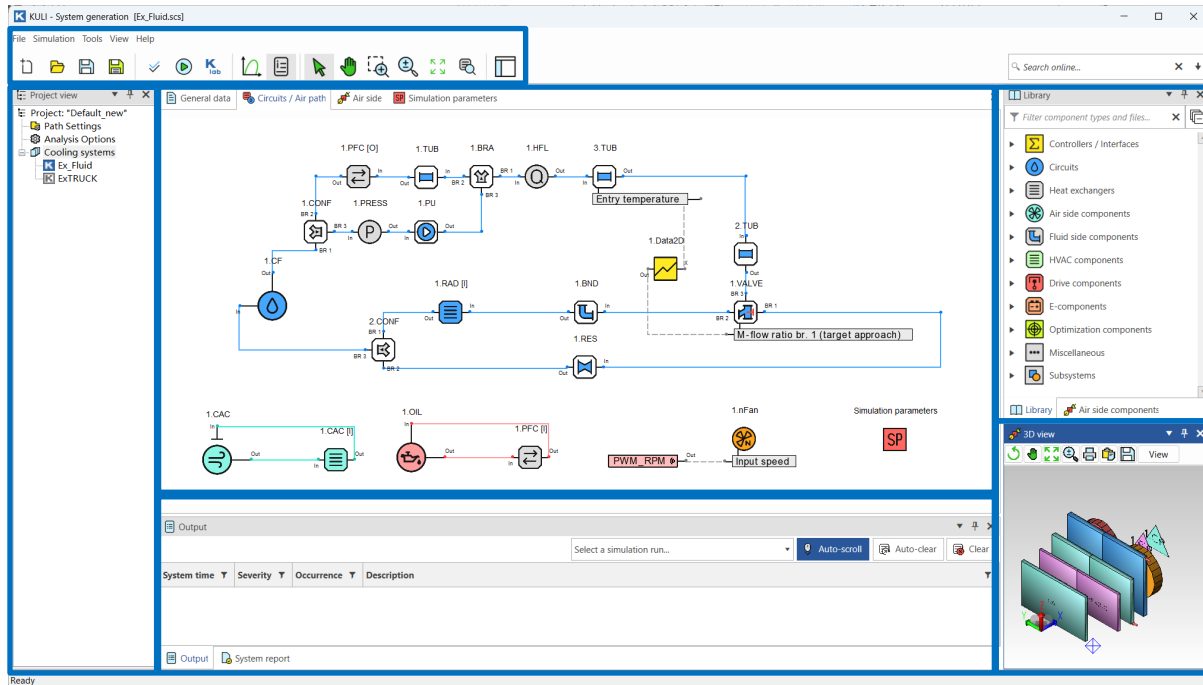


Menu & Toolbars  
菜单及工具栏

Project  
Organization  
项目组织

Components  
Library  
零部件数据库

Analysis  
Progress Info  
分析进度信息



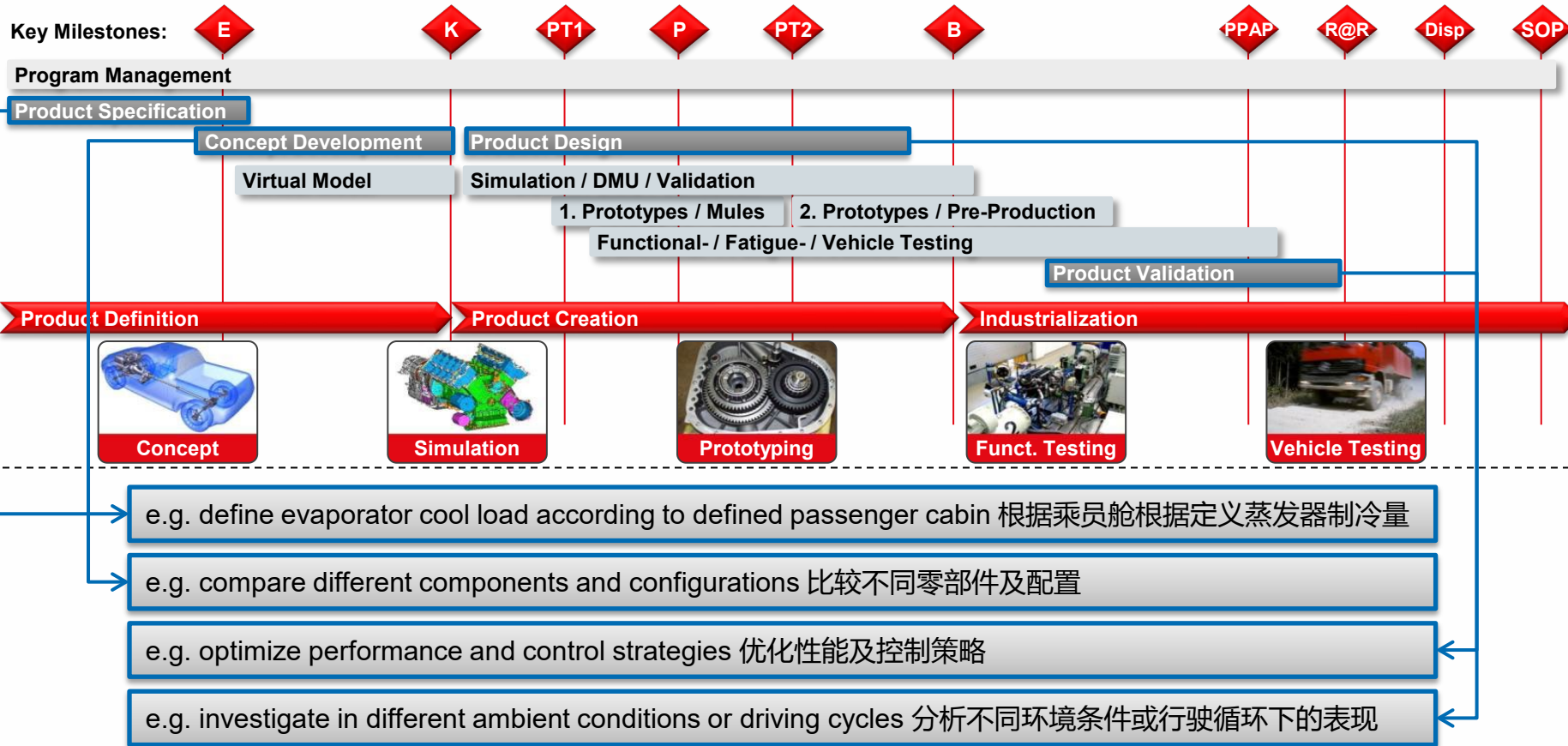
2D Fluid  
Network View  
二维视图

3D Air Network  
View  
三维视图

# KULI in the Product Development Process

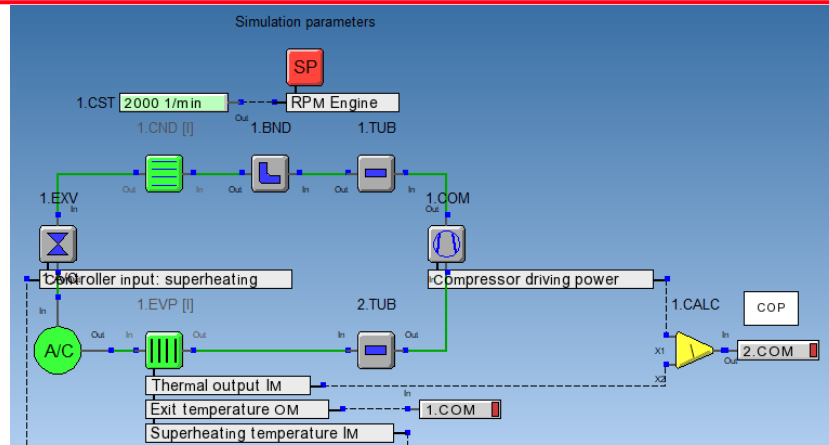
## KULI嵌入的产品开发流程

# Product Development Process 产品开发过程



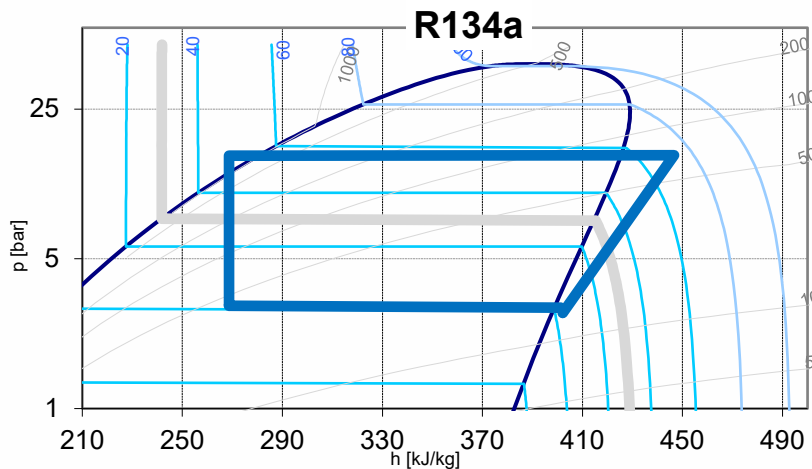
## Input 输入

- KULI data HX and compressor 热交换器和压缩机
- Volume flow data air side 空气侧体积流量
- Ambient temperature and humidity 环境温度和湿度
- TXV superheat curve 膨胀阀过热曲线
- Compressor speed 压缩机转速



## Results 结果

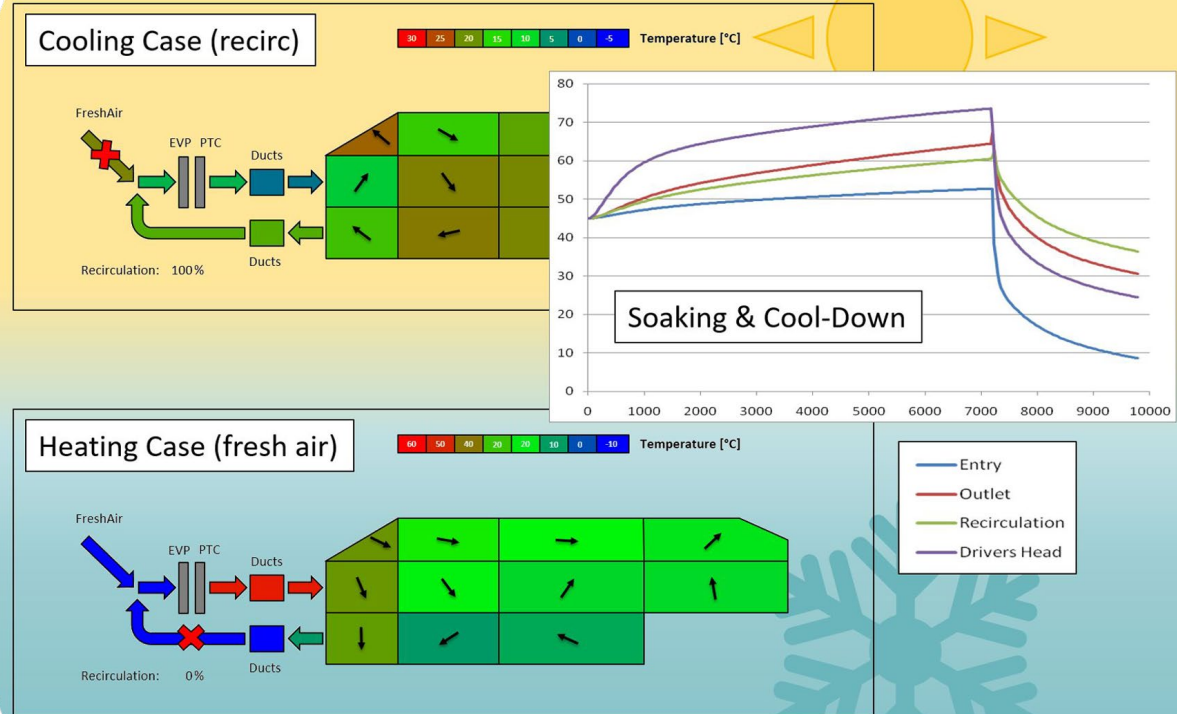
- Is Cool Load requirement met? 制冷量是否满足
- Evaporator air temperatures and dehumidification 蒸发器空气温度和除湿量
- Coefficient of performance (COP) 系统效率
- Surface temperatures of condenser / evaporator 蒸发器冷凝器表面温度
- Optional result: refrigerant charge 制冷剂充注量
- Variations: refrigerant type, compressor speed, HX flow configurations,... 变参数: 制冷剂类型, 压缩机转速, 换热器流量



# Cabin heating and cooling

- Develop Efficient Cooling and Heating Solutions!
- EV HVAC Systems can reduce Winter Range by 30-50% and Summer Range by >20%

**Simulation Ensures Sustainable Passenger Comfort!**



Example: Cabin HVAC Simulation VTM Model

# Typical Application – Cabin Cool Load Determination

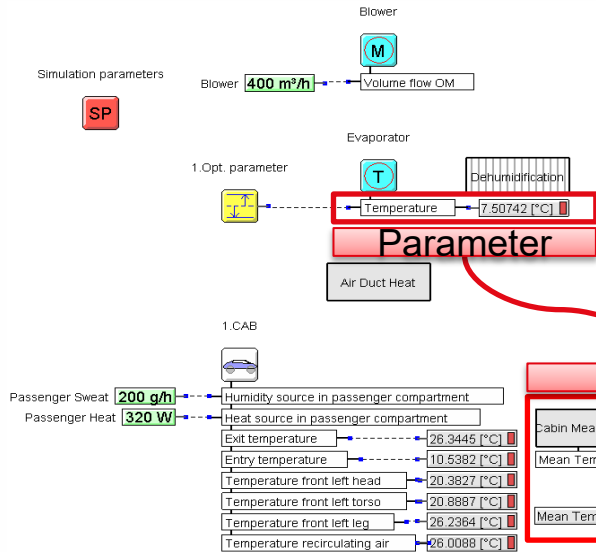
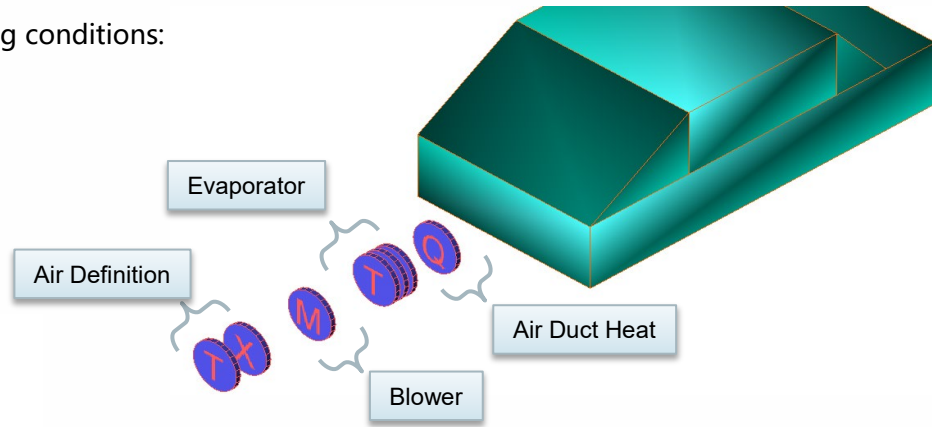
## 典型案例 – 确定乘员舱制冷负荷



- E.g. find cool load for mean target temperature 22°C at the following conditions:

例如：在以下条件找到要达到22度温度目标的制冷负荷

- Ambient 38°C, 40% humidity, solar load 1000W/m<sup>2</sup> at 45°;  
环境温度38°C, 相对湿度40%, 光照强度1000W/m<sup>2</sup>角度45°
- 4 Passengers (heat ~ 80W/person, humidity ~50g/h/Person)  
4名乘客 (热量~80W/每人, 湿度~ ~50g/h/每人)
- Vehicle at idle, A/C in recirculation mode, max. blower  
车辆怠速, 空调开启内循环, 鼓风机最大档

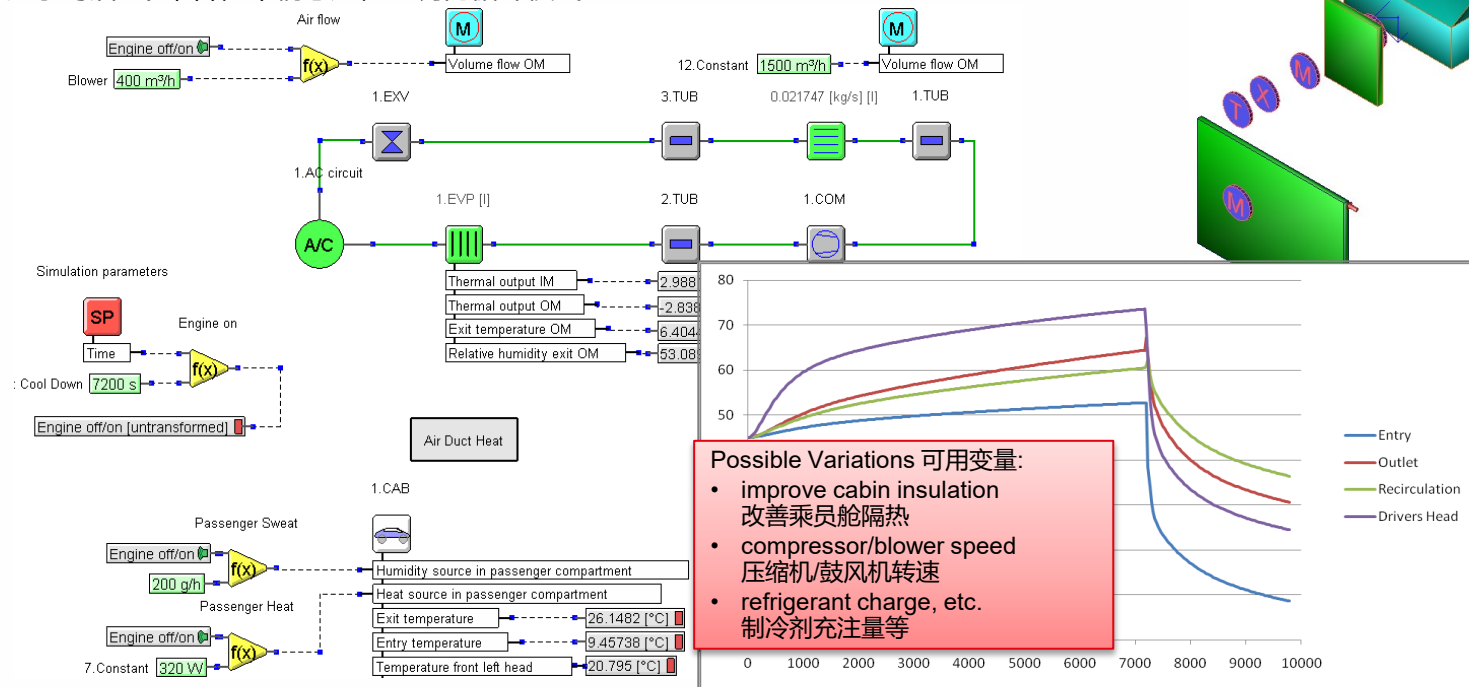


| M Air source                |             |
|-----------------------------|-------------|
| 2. Temperature target (Air) | 20120515_Es |
| Label / transient [s]       | 10800       |
| Comment                     | Evaporator  |
| Entry temperature [°C]      | 26.0088     |
| Exit temperature [°C]       | 7.50742     |
| Temperature difference [K]  | -18.5014    |
| Mass flow [kg/s]            | 0.130431    |
| Actual heat flow [kW]       | -2.44359    |

**Cool Load Requirement**

# Typical Application - Cool Down Simulation of the Passenger Cabin 典型案例 – 乘员舱温降仿真

- E.g. Cool Down mean target temperature 26°C after 30 minutes at the following conditions:  
例如：仿真计算以下条件下，乘员舱在30分钟温降至平均温度26°C
  - Ambient 38°C, 40% humidity, solar load 1000W/m<sup>2</sup> at 45°; 2 hours sun soak;  
环境温度38°C, 相对湿度40%, 光照强度1000W/m<sup>2</sup>角度45°; 2小时热浸泡
  - After 2 hours 4 passengers, vehicle at idle, A/C on in recirculation mode  
两小时后4个乘客，车辆怠速，空调内循环模式



**Possible Variations 可用变量:**

- improve cabin insulation  
改善乘员舱隔热
- compressor/blower speed  
压缩机/鼓风机转速
- refrigerant charge, etc.  
制冷剂充注量等

# Other Applications

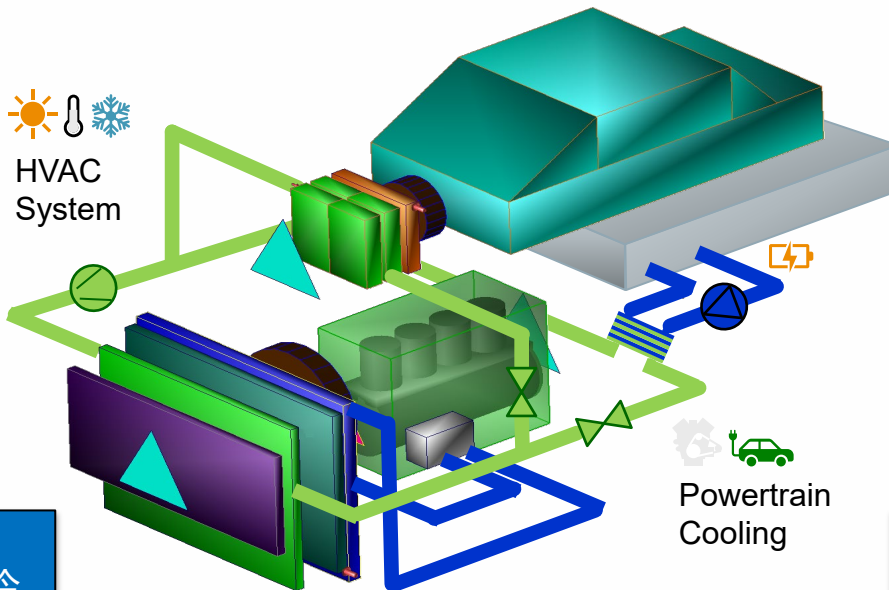
## 其它应用

# Combined Powertrain Cooling and HVAC 结合动力总成冷却及空调系统

- Radiator 散热器
- Charge Air Cooler 中冷器
- Viscous and E-Fans 离合器及电子风扇
- Air Resistances 空气阻力
- Cp-Vaules CP值
- Grill 格栅



HVAC System



## Powertrain Cooling 发动机冷却

Influence of HVAC on powertrain cooling 空调和冷却系统之间的相互影响

## Air Conditioning Heat pump 空调热泵

- Evaporator 蒸发器
- Condenser 冷凝器
- Compressor 压缩机
- Expansion Valve 膨胀阀
- Pipes 管路
- Heaters 暖风芯体

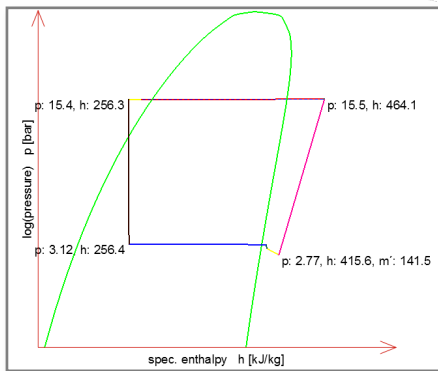
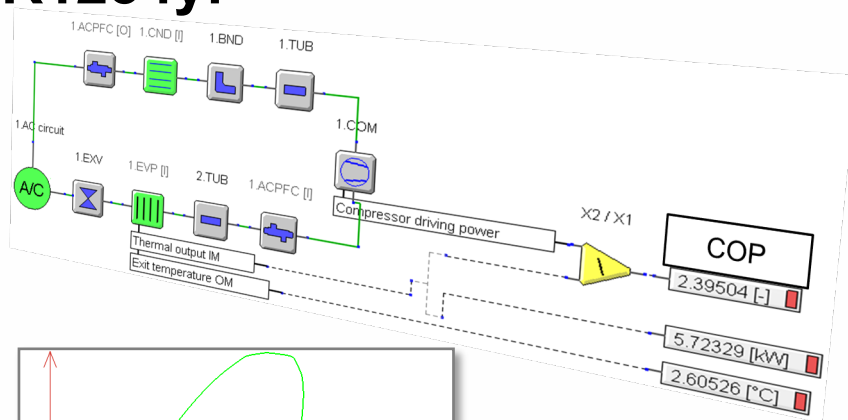
Complete system consideration  
系统级理解

Only to combine both circuits it is possible to increase or optimize the thermal efficiency of vehicles  
只有结合两个回路才能更好地提升和优化车辆效率

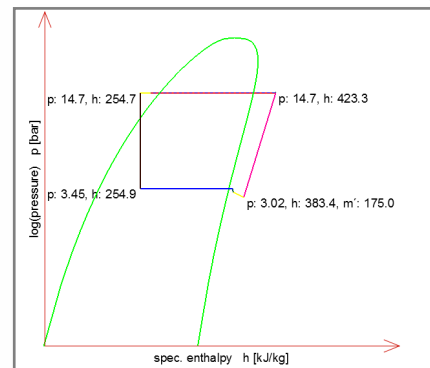
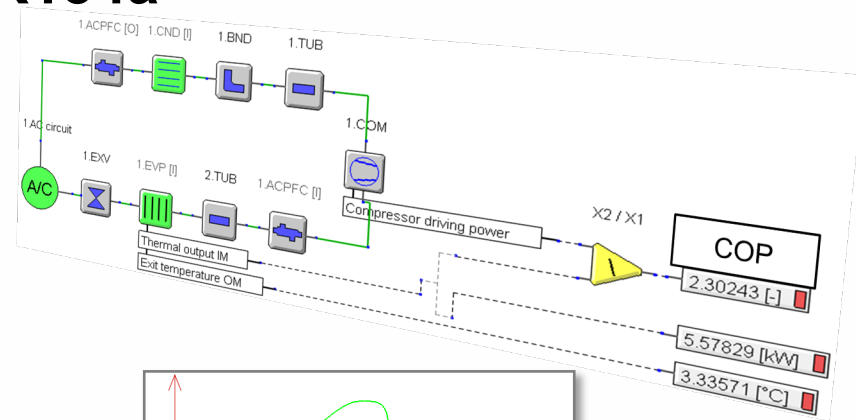
# Typical Application – Refrigerant Comparison

## 典型案例 – 制冷剂对比

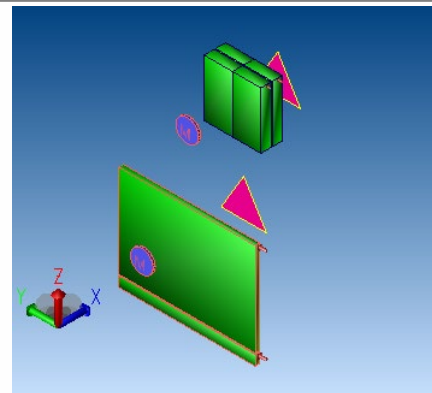
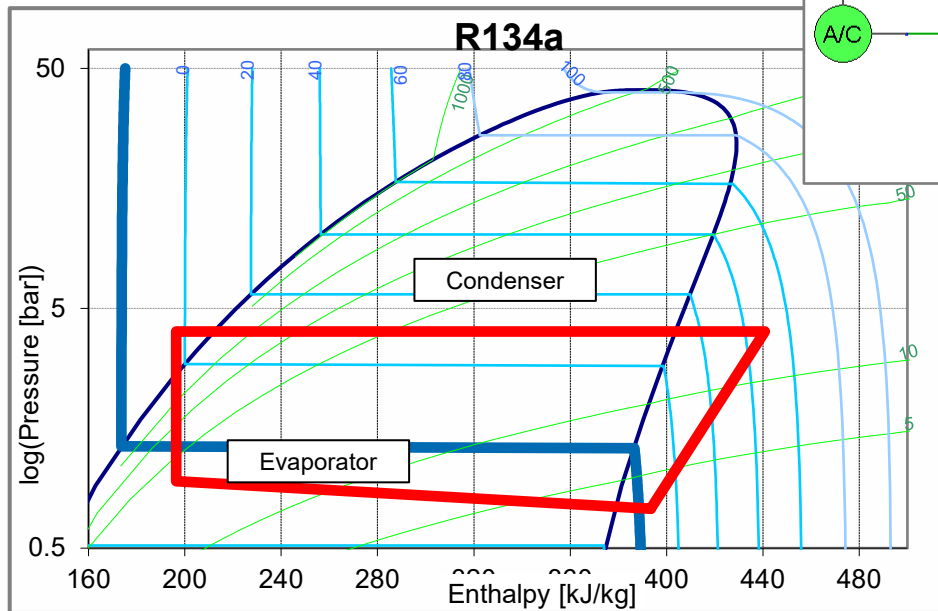
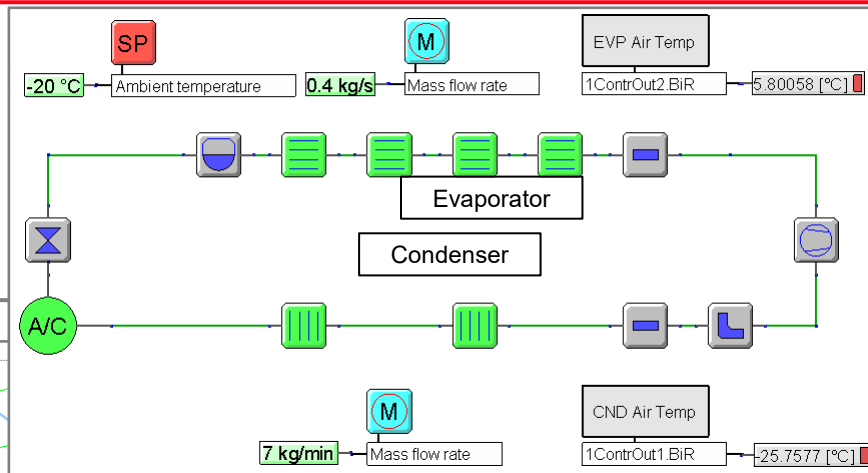
### • R1234yf



### • R134a

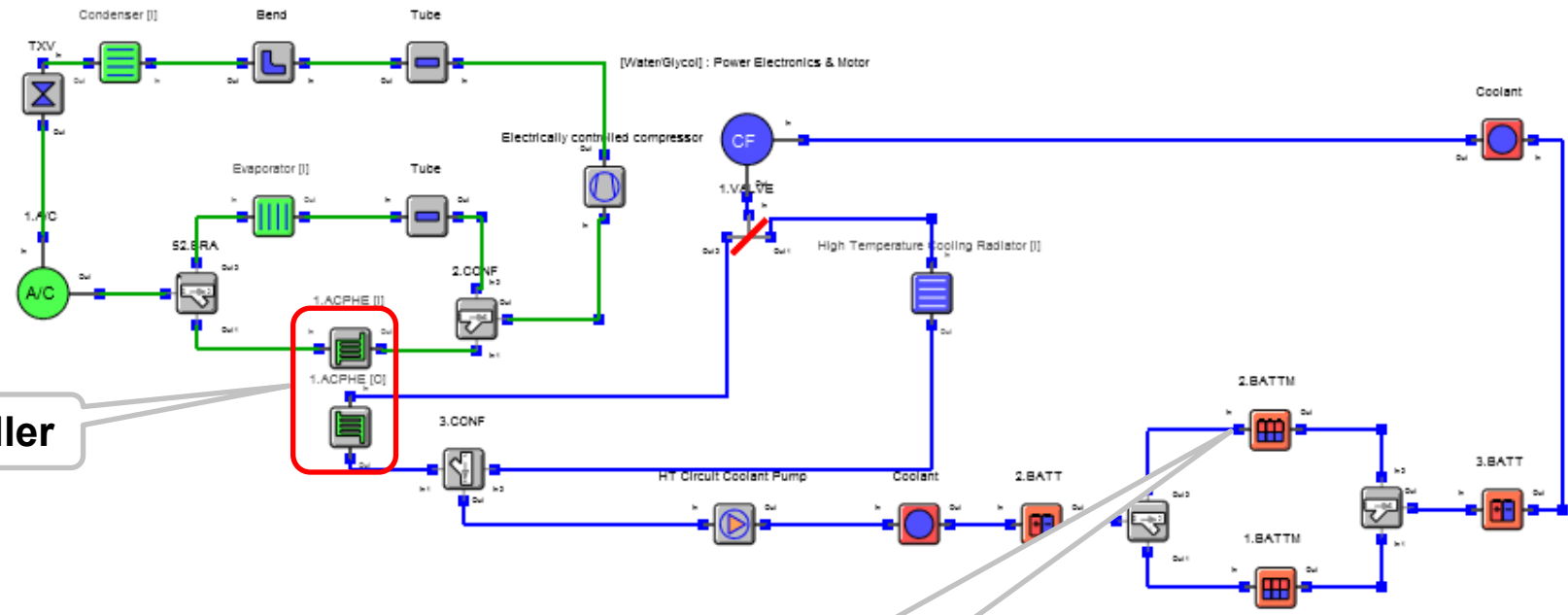


- Evaluate Performance of HVAC system when switched over to Heat Pump 评估空调系统切换至热泵的表现**



## A/C circuit 空调回路 (dual loop)

## Coolant circuit 冷却回路



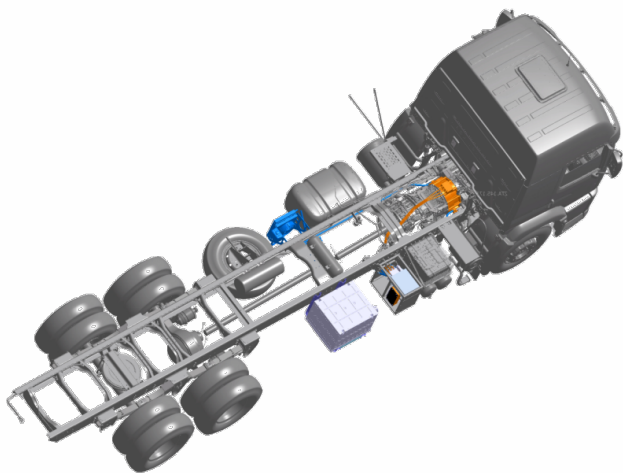
Chiller

Battery cooling  
电池冷却

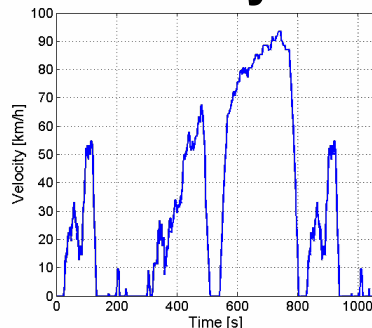


### Energy Management Simulation for a Hybrid Truck

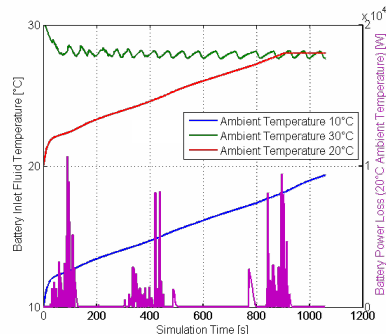
#### 混合动力卡车能量管理



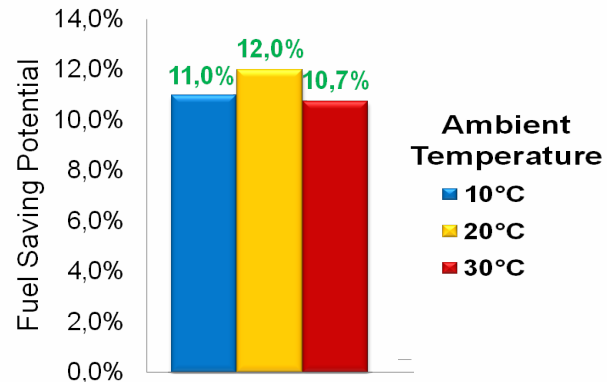
Parallel Hybrid Vehicle  
并行式混合动力



Driving Cycle (HUDDS)  
Heavy-Duty Urban Dynamometer Driving Schedule



Battery, Coolant Temperature



HUDDS  
Fuel Saving Potentials  
节油潜力

# Circuits & Components

## 循环回路及零部件

1.CND [I]



## Condenser

1.EVP [I]



## Evaporator

1.COM



## Compressor: Uncontrolled, Controlled

1.EXV



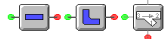
## Expansion Valve: TXV, Orifice Tube, EXV

1.STO



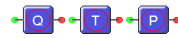
## Storage Tanks: Accumulator, Receiver

1.TUB 1.BND 1.BRA



## Tubes, Bends, Manifolds, Valves, Lock-Valves

1.HFL 1.TEMP 1.PRESS



## Targets: Heat Flow, Temperature, Pressure

1.ACPFC [I] 1.ACPFC [O]



## Internal Heat Exchanger

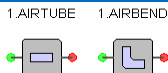
1.ACPHE [I] 1.ACPHE [O]



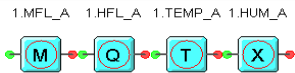
## Plate Heat Exchanger (“Chiller”)



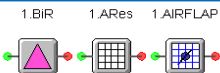
**Passenger compartment**



**Air Tube, Air Bend (-> Air ducts)**



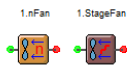
**Sources: Mass-/ Heat flow, Temperature, Humidity**



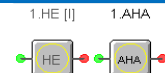
**Resistances: Built-in, Area, Air flap (Pollen filter)**



**$c_p$ -values:  $c_p$ , Inlet Grid**

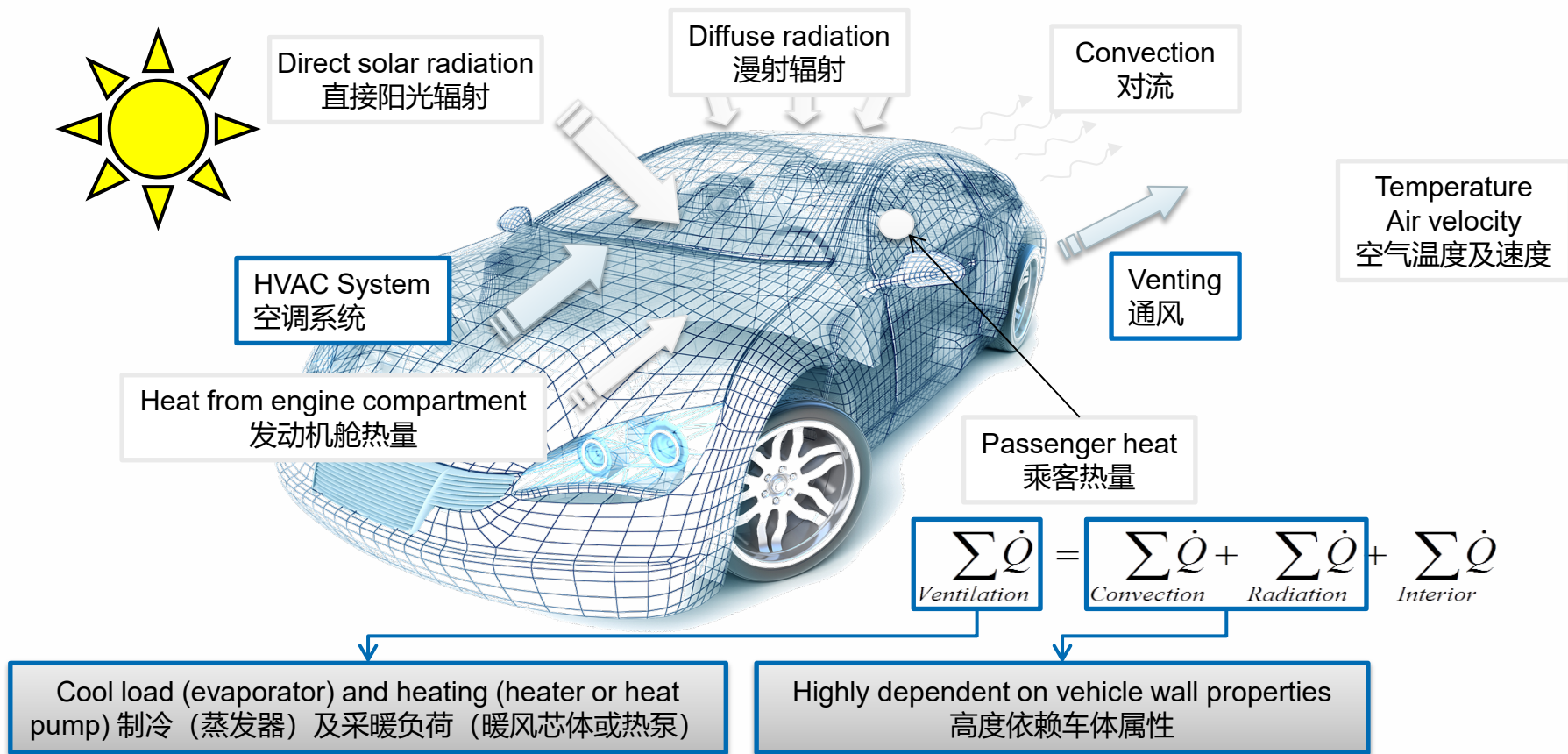


**Fans: Speed-controlled, Stage-controlled**



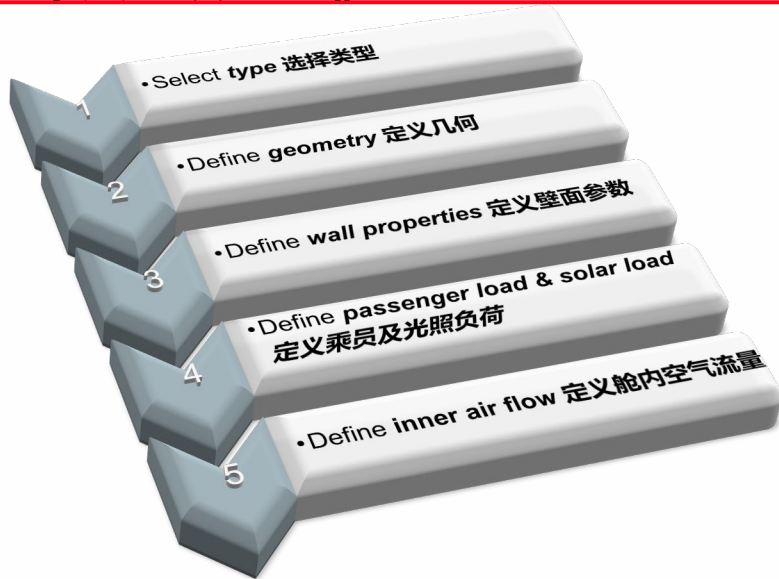
**Electro Heater: Air, Water**

# Passenger Compartment 乘员舱模型



# KULI Cabin Model – Input Overview

## 乘员舱模型 – 输入一览



**1** Select car type

**2** Geometric parameters table:

| ID        | Wert |
|-----------|------|
| a [m]     | 1.11 |
| b [m]     | 0.99 |
| c [m]     | 0.8  |
| d [m]     | 0.3  |
| e [m]     | 0.38 |
| f [m]     | 0.45 |
| g [m]     | 0.62 |
| h [m]     | 0.23 |
| l [m]     | 0.42 |
| alpha [°] | 34   |
| beta [°]  | 18   |
| gamma [°] | 47   |

**3** Wall and door properties

**4** Air ventilation settings

**5** Interior air flow settings

$$\sum \dot{Q} = \sum \dot{Q} + \sum \dot{Q} + \sum \dot{Q}$$

*Ventilation*      *Convection*      *Radiation*      *Interior*

The right hand side of the heat balance is defined by the cabin model  
 右侧热平衡根据乘员舱模型定义

The cabin model can be used to...乘员舱模型可被使用在

Simulate different initial conditions  
不同初始条件

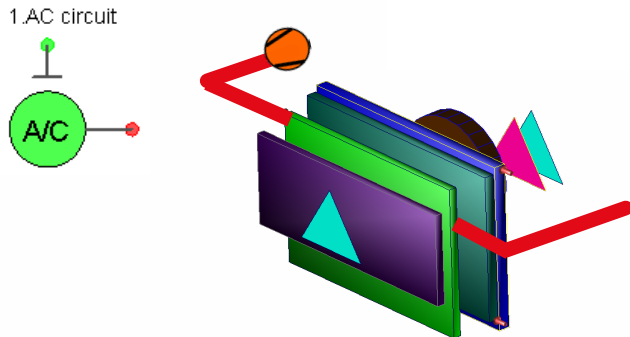
Simulate additional heat and humidity sources  
不同额外热源和湿度

Simulate different sun radiation conditions  
不同光照辐射

Simulate different internal air-flow conditions  
模拟不同舱内流量条件

Simulate the interactions between cooling system and cabin comfort level.  
仿真不同乘员舱舒适度对于冷却系统的影响

## • Open 开环

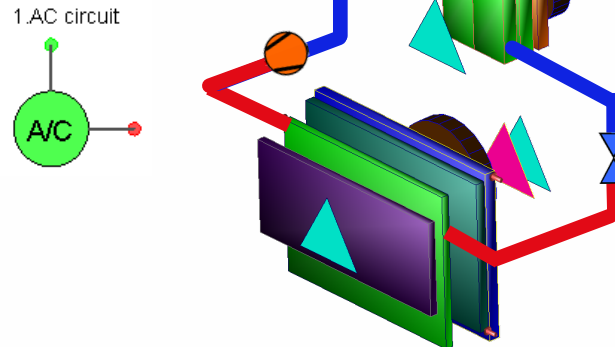


**Open:** Inlet properties

### – Predefine 预定义

- Mass flow 质量流量
- Start pressure 起始压力
- Start Enthalpy 起始比焓

## • Closed 闭环



**Closed:** Equalization

### – Equalization 平衡求解

- $\sum \text{Heat flow} = 0$
- $\sum \Delta p = 0$
- predefined refrigerant charge  
预定义制冷剂充注量

## Compressor Speed 压缩机转速

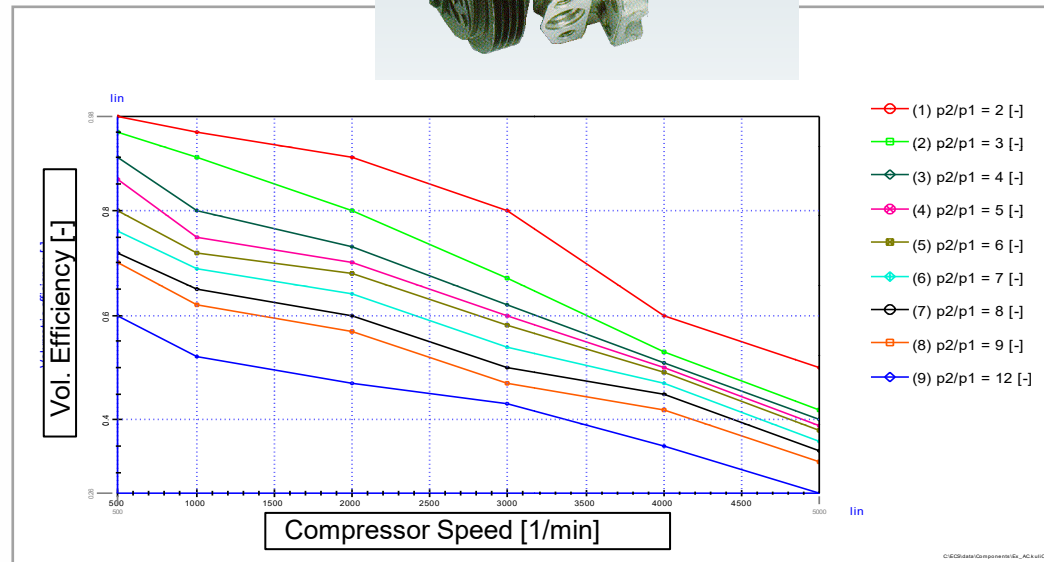
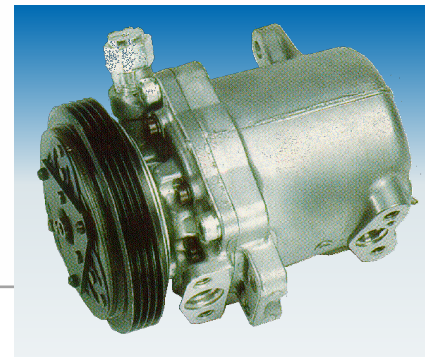
## Piston Displacement (Range) 活塞式容积

## Efficiency Characteristics 效率特性

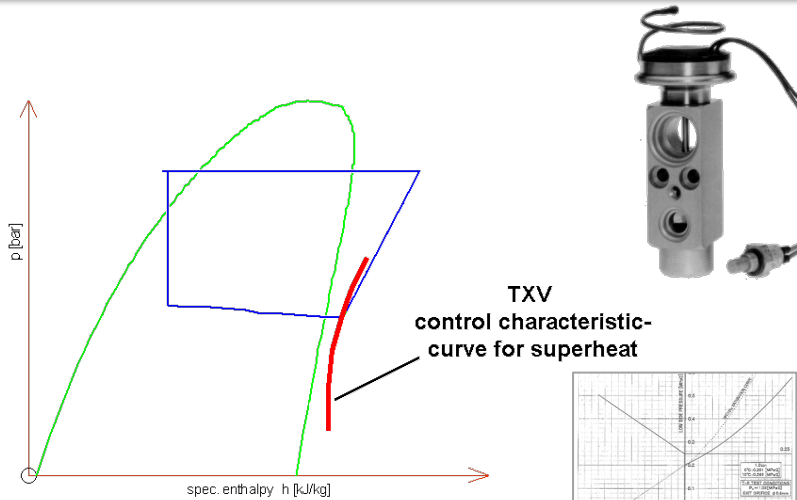
- Volumetric 体积效率
- Isentropic 等熵效率
- Mechanic 机械效率

## Control Strategies 控制逻辑

- Uncontrolled 不可控式
- High pressure controlled 压控式
- Internal controlled 内控式
- External controlled 外控式
- User defined (-> E-Compressor) 自定义

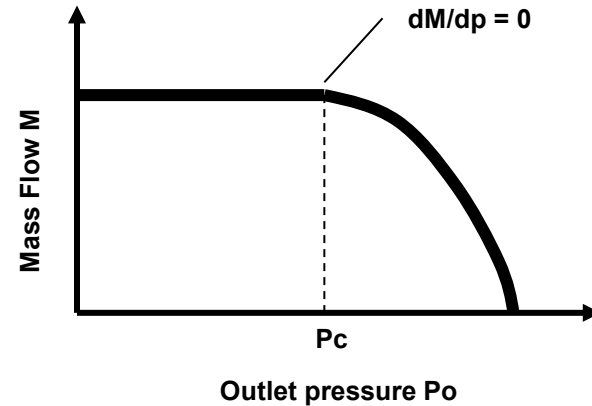


## Thermostatic Controlled 热力式



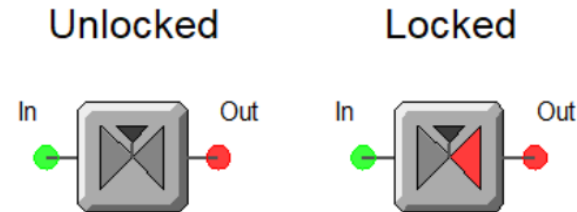
- Simple Model 简单模型
- 4-Quadrant Model 四象限模型

## Orifice Tube 节流式

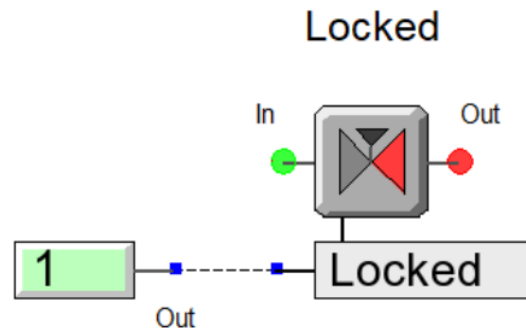


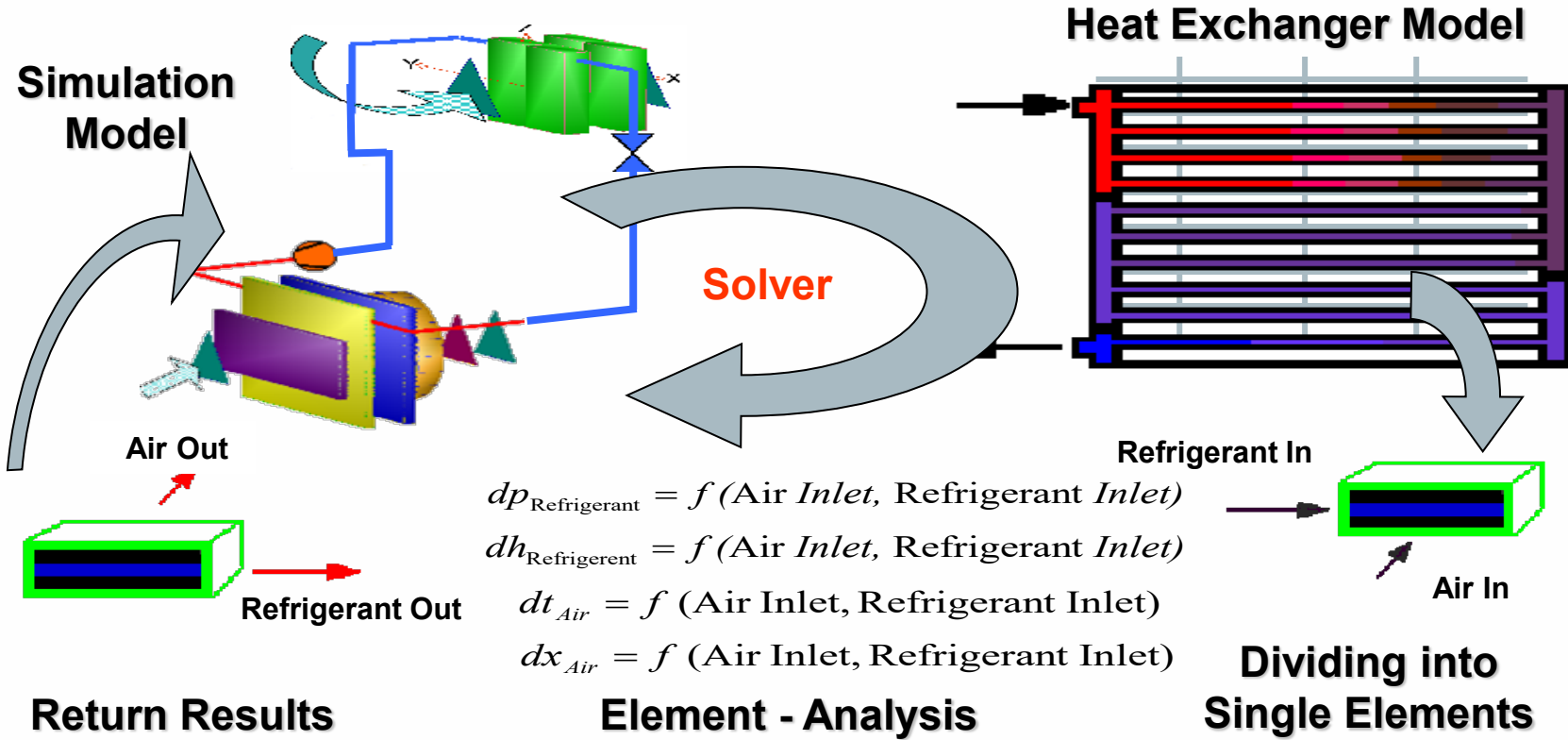
- Fixed Orifice Tube 固定阀口
- Variable Orifice Valve 可变阀口

- Typically, in bigger A/C systems, there is more than one parallel branch containing a heat exchanger. Depending on the operating point it sometimes is necessary to completely shut-off a specific branch.  
通常，在较大的 A/C 系统中，有多个包含热交换器的并联支路。根据工况点的不同，有时需要完全关闭特定的支路。
- The *Shut-off valve* component provides one inlet and one outlet and is used in refrigerant circuits to do exactly that.  
截止阀组件提供一个入口和一个出口，并在制冷剂回路中用于实现此目的。
- The *Shut-off valve* has 2 states: **Unlocked** and **Locked**  
截止阀有 2 种状态：解锁和锁定

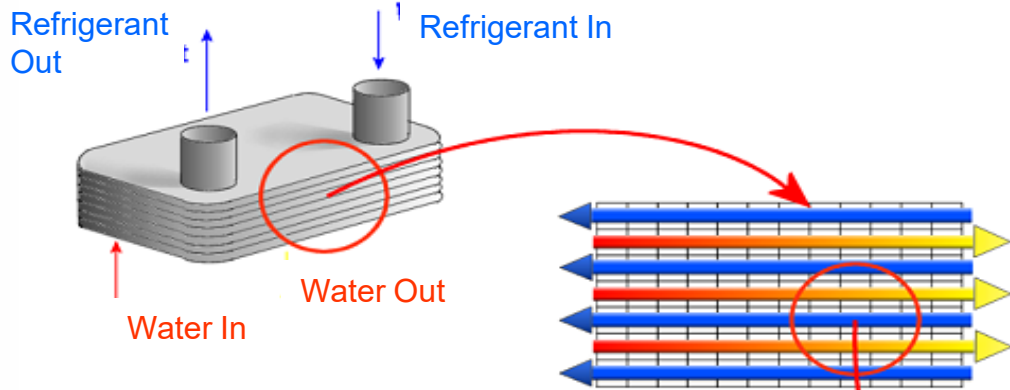


- This can also be set via an actuator 这可以通过设定执行器完成,
- The input of the actuator can be set via 执行器输入可以是:
  - A constant 一个常量
  - A signal receiver (setting the locked state in the simulation parameters in transient simulations)  
一个信号接收器 (在瞬态仿真参数中设定期锁止状态)
  - By using any controller in KULI (CALC, PID, ...)  
使用KULI控制器 (计算、PID对象)
  - COM COM接口





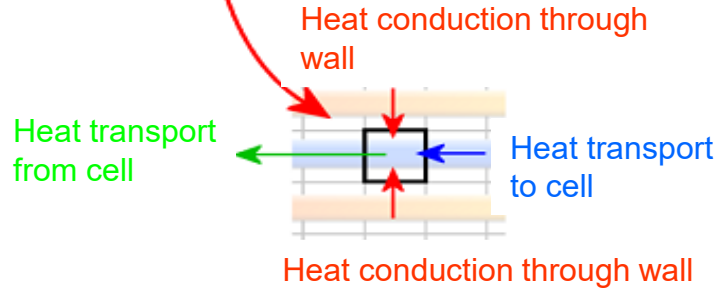
# KULI hvac – Plate Heat Exchanger 板翅式热交换器



Heat from above  
 + Heat from below  
 + Heat transport by fluid

---

Changed Heat in Cell



AC Plate Heat Exchanger [EuCPHE.kuliacpche]

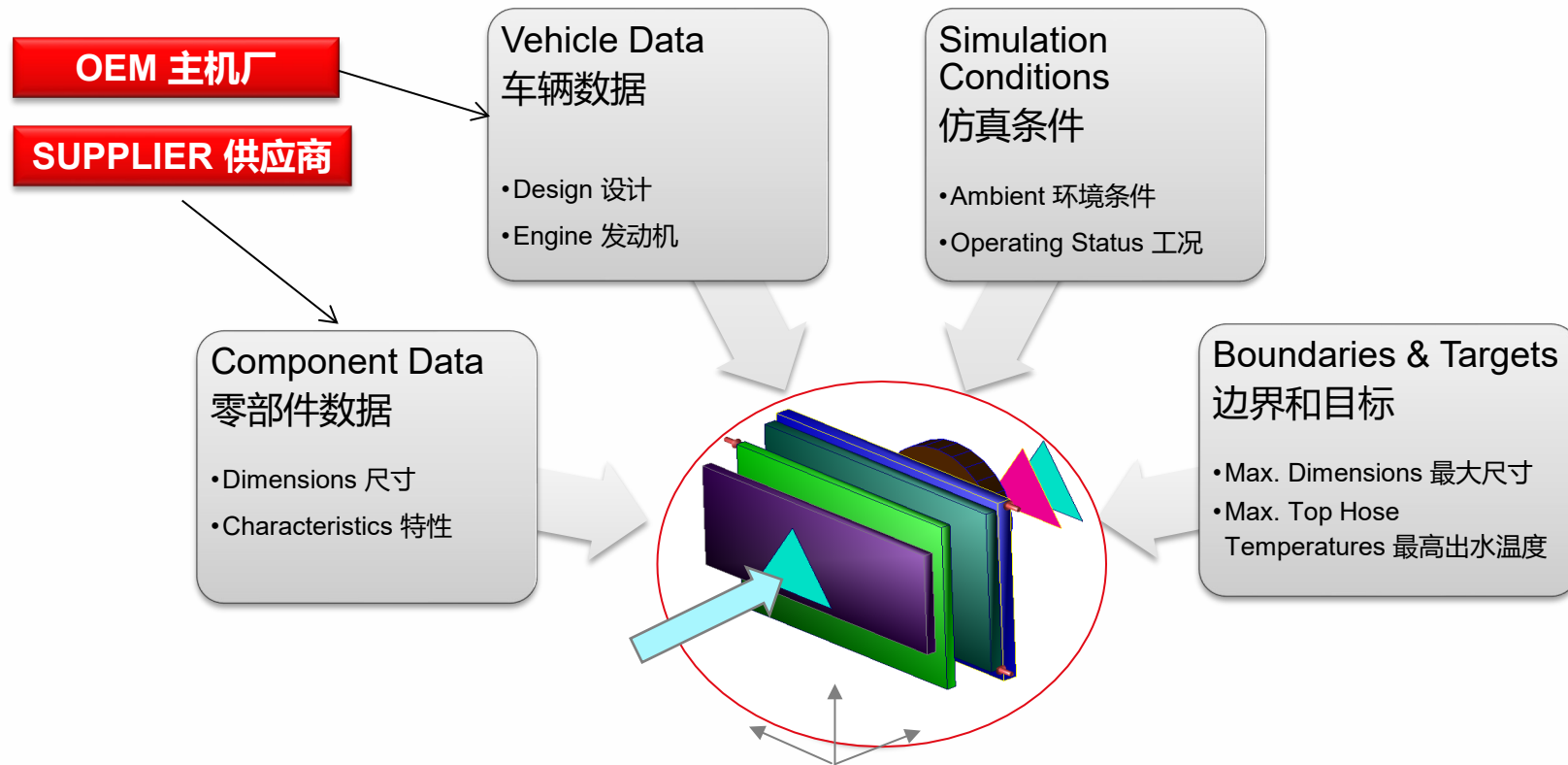
Heat exchanger type: AC Plate Heat Exchanger

| Inner flow rate [kg/h]... | Outer flow rate [m³/h]... | Exchanged heat [kW]... | Inner pressure drop [bar]... | Outer pressure drop [bar]... | Inner entry enthalpy [kJ/kg]... | Inner entry pressure [bar]... | Outer entry temperature [°C]... | Outer entry pressure [hPa]... |
|---------------------------|---------------------------|------------------------|------------------------------|------------------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|
| 26.6475                   | 0.55                      | 1.00833                | 0.01                         | 0.05                         | 257.395                         | 2.441                         | 2                               | 1013                          |
| 27.9767                   | 0.44                      | 1.00833                | 0.01                         | 0.04                         | 257.395                         | 2.441                         | 2.5                             | 1013                          |
| 63.3058                   | 0.33                      | 1.1                    | 0.01                         | 0.03                         | 252.072                         | 2.441                         | 3.5                             | 1013                          |
| 66.6142                   | 0.55                      | 2.475                  | 0.02                         | 0.03                         | 254.303                         | 2.441                         | 8                               | 1013                          |
| 69.2817                   | 0.44                      | 2.56667                | 0.02                         | 0.05                         | 254.909                         | 2.441                         | 5                               | 1013                          |
| 79.9425                   | 0.33                      | 3.11667                | 0.03                         | 0.03                         | 255.486                         | 2.441                         | 6.5                             | 1013                          |
|                           |                           |                        |                              |                              | 253.267                         | 2.441                         | 10                              | 1013                          |

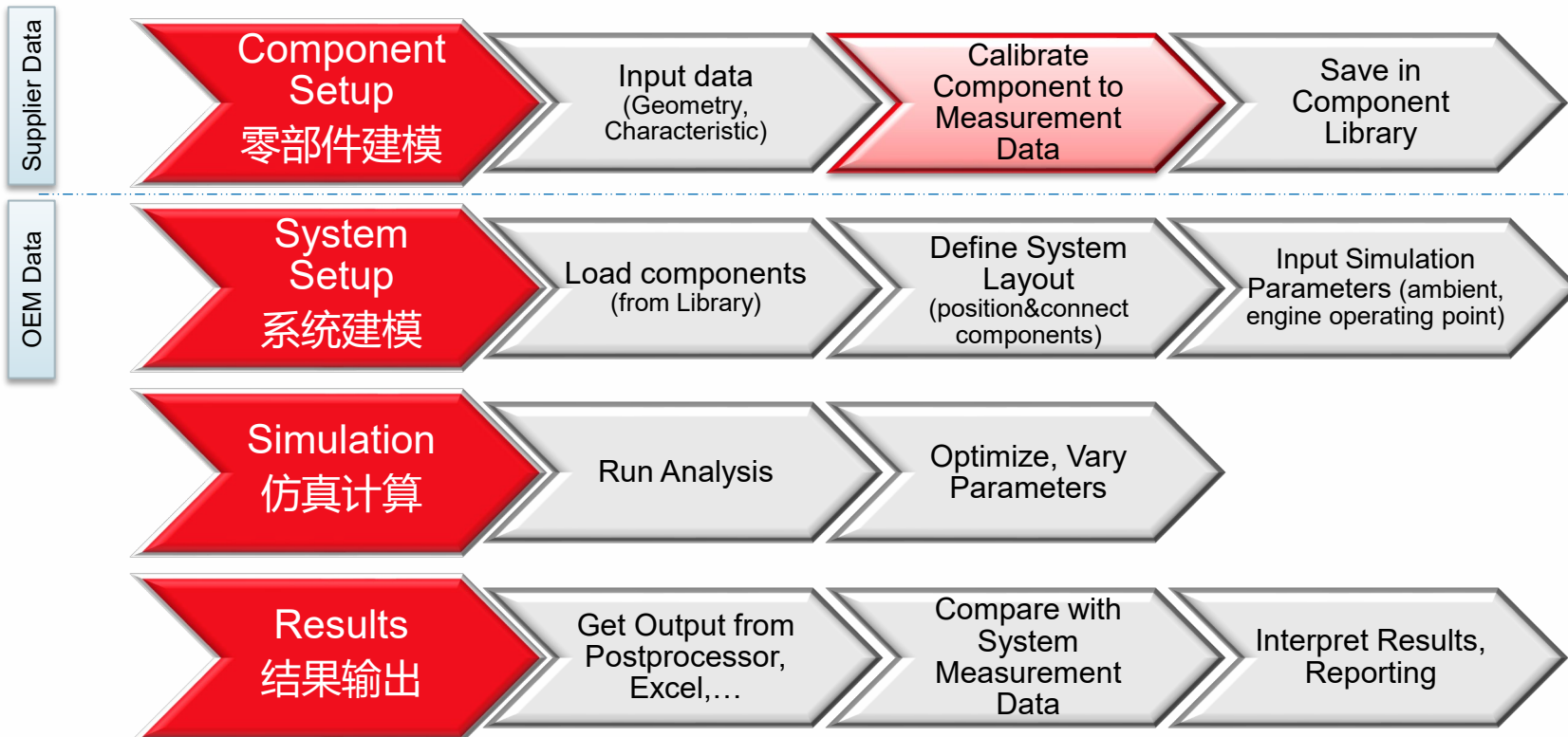
# How to use KULI hvac? 如何使用KULI hvac?

# How to use KULI? – Data Structure

## 如何使用KULI – 数据结构



# How to use KULI? – Workflow 工作流程



# How to use KULI? – KULI lab Output 结果输出

Temperature levels  
and Pressure Drops  
温度以及压力损失

Heat Turn-over and  
Efficiency of Package  
热量传递以及系统效  
率

Detailed Conditions  
and amounts of  
Cooling Air  
详细的冷却空气条件  
和风量

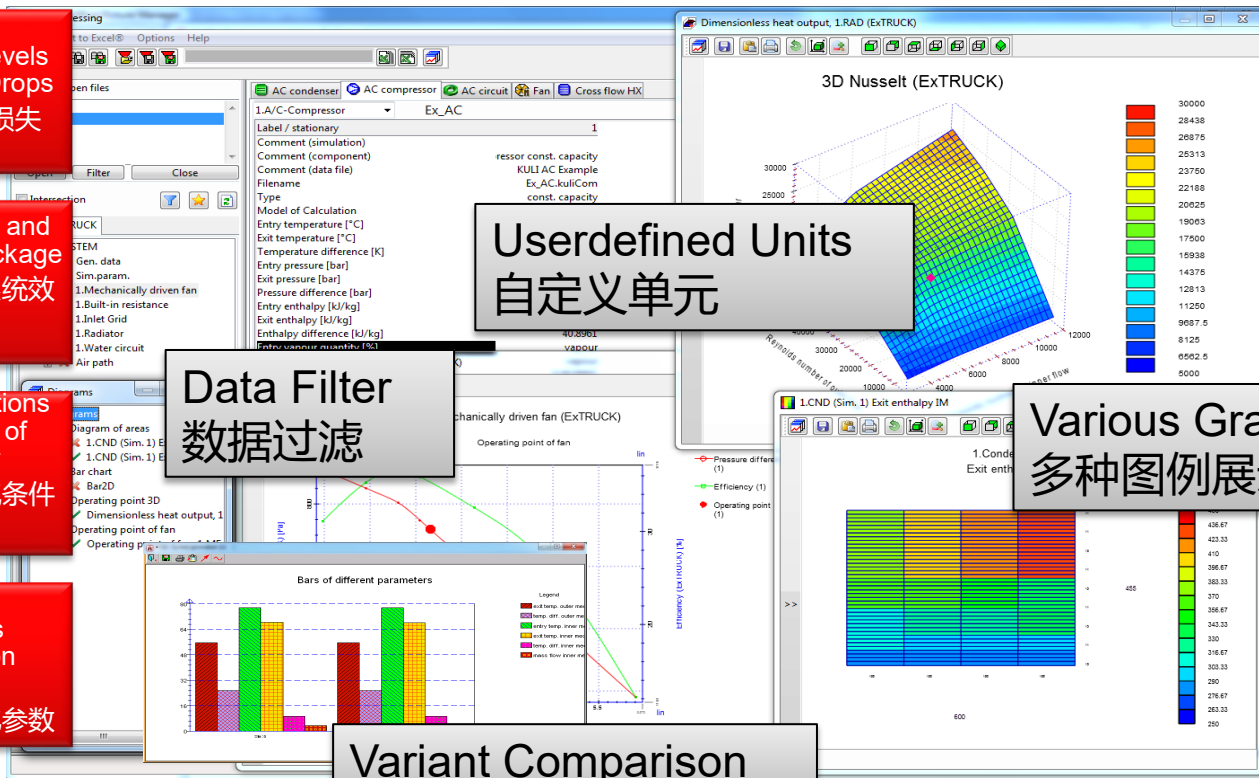
Optimized  
Parameters  
depending on  
Targets  
根据目标优化的参数

Userdefined Units  
自定义单元

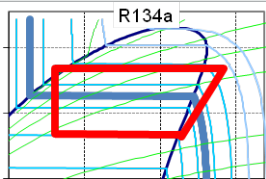
Data Filter  
数据过滤

Various Graphics  
多种图例展示

Variant Comparison

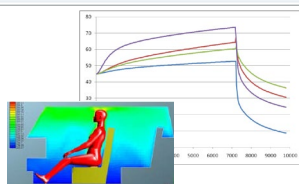


# Benefits 优势



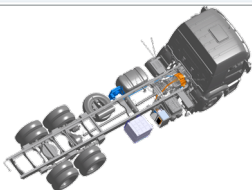
Quick analysis of refrigerant two-phase flow and heat-transfer for any refrigerant

针对于任意制冷剂的快速二相流分析



Improved passenger comfort due to faster cabin warm-up (or cool-down)

由于乘员舱快速温升（或温降）而提升的舒适性



Easily investigate in new technologies like HEV/EV cooling systems

轻松分析新技术在混合动力/电动车冷却系统的应用